Traction Drive RE Magnet NA Supply Chain Assessment: Trends, Gaps and Anticipated Strategic Moves of Interest to VTO R&D Planners

Christopher Whaling, PI

Richard Holcomb III, Manager
Steve Johnson, Senior Researcher
Michael Willis, Senior Policy Analyst
Ryan Bunch, Research Analyst

Synthesis Partners, LLC

Project ID #
ELT089

For delivery Tuesday, June 2, 2020 at 830AM ET.
US Department of Energy's, Vehicle Technologies Office, Annual Merit Review (AMR) meeting.

Caveats

- ✓ Nothing stated in this brief is an official viewpoint of the US Department of Energy or any other official US government entity.
- ✓ Synthesis Partners makes no warranty, express or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed herein.
- ✓ This is an interim product and findings will change, esp. as market conditions change and new data is developed.

Overview

Timeline

- Start: November 2019
- End: September 2020
- Percent complete in April 2020: 45%

Budget

- Total project funding
  - DOE share: 100%
- Funding received in FY19: $219,958
- Funding received in FY20: $219,958

Barriers

- "Enable reliable hybrid electric, plug-in hybrid and range-extended electric, and battery electric vehicles with performance, safety, and costs comparable to or better than advanced conventional vehicle technologies." (USDRIVE Partnership Goal 1 (Nov. 2016)).
- Accurate information about the current state of RE traction drive magnets and their supply chains in North America.
- Actionable intelligence on R&D opportunities that can help strengthen RE supply chains, EVs and Autonomous Vehicles in North America.

Partners

Interactions/ collaborations

- Interactions with 100s of primary sources @ OEMs, Tier 1-4s, R&D organizations & Universities.
- US DRIVE Electrical/ Electronics Technical Team members.
- NREL and ORNL links to coordinate information.
- Project lead: Synthesis Partners, LLC

Relevance: Progress Toward Objectives

Overall Objectives (FY20)

- Produce report on results of past (FY19) NA EVSE Supply Chain gap analysis work.
- Targeted collection and analysis regarding the state of the RE supply chain relevant to North American (NA) RE traction drive magnets, including gaps, bottlenecks and needs.
- Share and collaborate with related VTO RE magnet supply chain assessment activities.

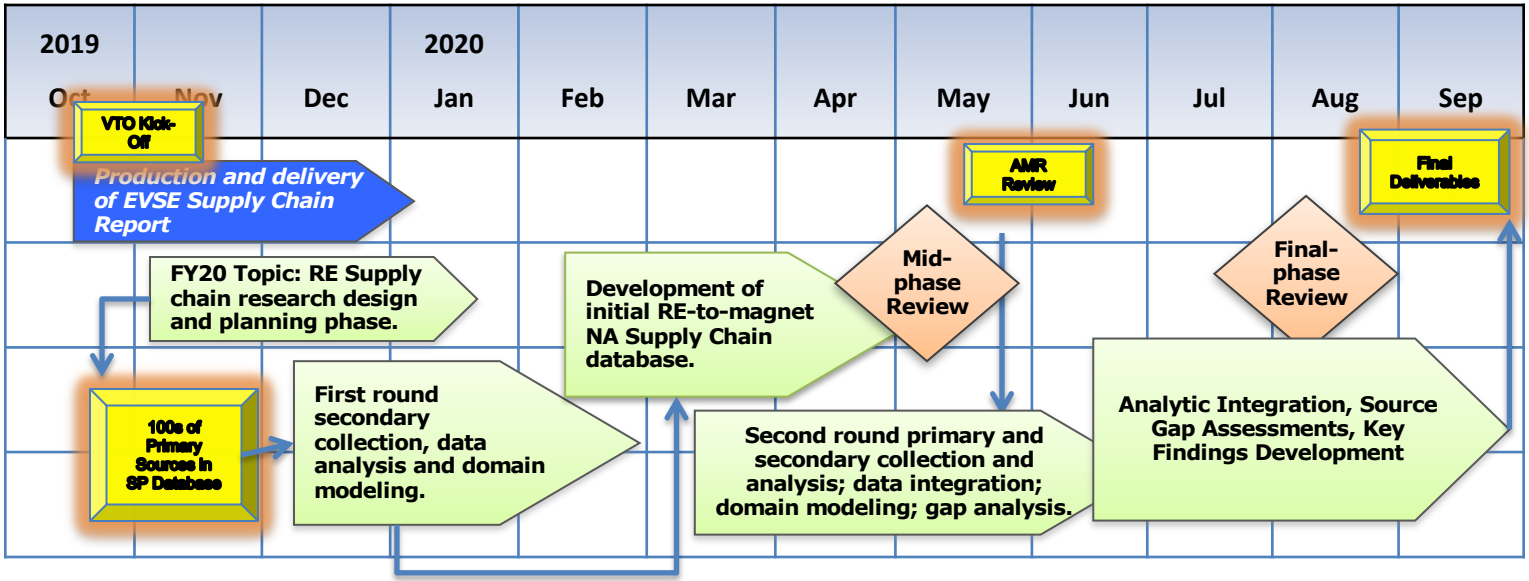
Progress toward objectives during reporting period (October 2019-April 2020)

- Issued report: "R&D Gap and Trend Analysis for Autonomous and Connected Vehicles: On Connectivity, Sensors and Sensor Systems," (November 2017). Available to the public.
- 250+ individuals identified (Jan-March 2020) to elicit information regarding RE supply chain relevant to North American (NA) RE traction drive magnets.
- Produced initial RE supply chain supply chain and formatted data for entry into database.
- Identified NREL and ORNL RE 2020 supply chain assessment activities and coordinated information.

Impact

- Deliver monthly independent, integrated assessment of SME views on gaps in the RE supply chain relevant to NA traction drive magnets, R&D planning and COVID-19 impacts.
- Decision support through integrated gap intelligence developed from comprehensive, custom-built databases of qualitative and quantified information about EV supply chain.
- Enabling increased accuracy and precision in decision-making regarding R&D surrounding the NA supply chain for RE traction drive motor magnets and revitalized NA mine-to-magnets strategies.

Project Milestones

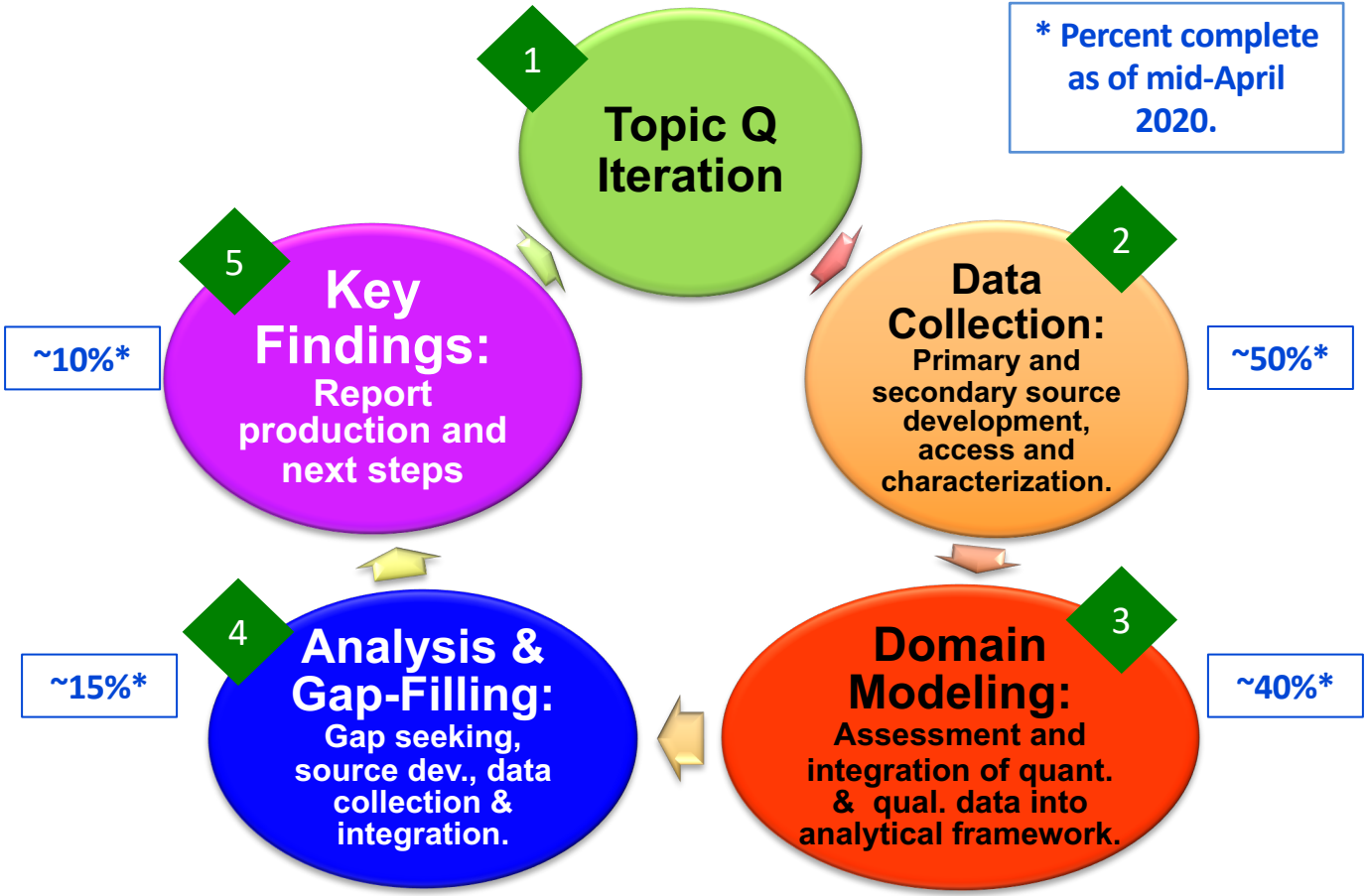


Go No/Go Decision Points: Monthly assessments, mid- and end-of-phase reviews.

Challenges/Barriers: Time to process and analyze large amounts of heterogeneous data for which key variables are not known ahead of time; rapid navigation to highest-value sources; confidentiality agreements; time to drill-down with SMEs on COVID-19 impacts.

Key Deliverables: Monthly presentations; Final Report; Database findings.

Technical Approach



* Percent complete as of mid-April 2020.

Technical Approach Details

- Completed November 2019: Integrated FY19 findings and produced public report on NA EVSE supply chain and gap analysis. [Public Report available.]

- **Ongoing: Jan. - April 2020:** English-language primary and secondary data collection to develop a baseline and model the RE traction drive magnet domain (Dy, Nd, Pr), integrating quantitative and qualitative data on:
  i. Key players (e.g, Ranked by revenue, production categories, links to automotive);
  ii. Market linkages (e.g., Who controls what or whom?);
  iii. Market trends (e.g., What technologies or processes are increasing or decreasing in relevance?)
  iv. 5-year projections for the market for RE minerals and metals used in motor magnets.
  v. 10-year land-based EV motor magnet R&D planning issues, given the major forces shaping the evolving RE minerals and metals as described in the current state and five-year projections.

- **Next phase: May 2020 forward:** Employ the information and insights obtained above to drive future modeling, projections, gap assessments and conference attendance to produce R&D planning insights on Dy, Nd, Pr supply chain issues.

Technical Accomplishments

- *Actionable Intelligence* technical accomplishments include (details, next slides):*
  - *[Approach Element #2] Collected comprehensive supply chain information; Identified key gaps and gap-filling on-going; Initial database covering relevant players and their automotive linkages 80% complete.*
  - *[AE #3] Initiated modeling and production of post-COVID-19 RE mine-to-magnet supply chain quantitative projections; Assessed relevance of price movements in global RE-to-magnet markets; Analyzed timing of RE-to-magnet developments and their impact on R&D planning efforts.*
  - *[AE #4]: Just 15% complete but have identified numerous disruptive RE-to-magnet technology and process opportunities – potential Future Research pathways – to-date.*
  - *[AE #5]: Key findings phase just beginning. A lot we still do not know.*

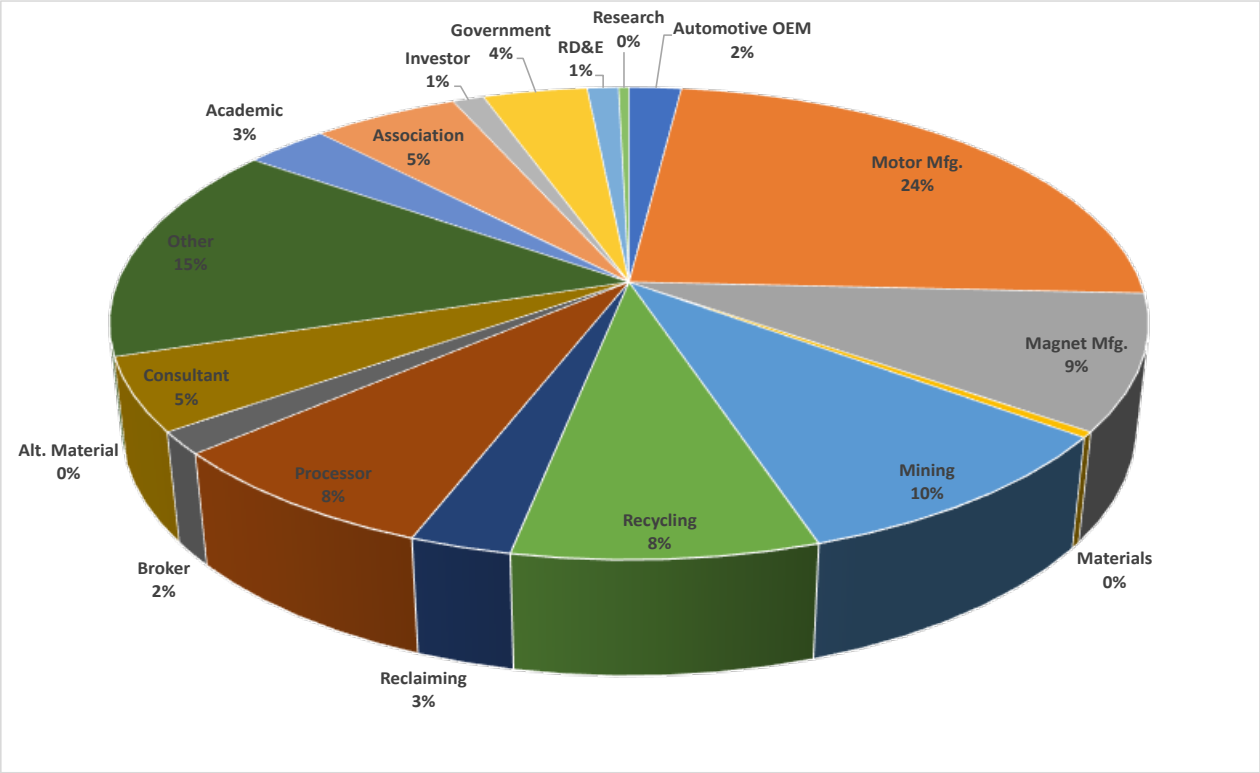
> **** Actionable Intelligence.***
> - What we know.
> - What we do not know.
> - What we think.

- *In-depth collection, data categorization and modeling via esp. SME-interviews and key player estimates; projections on-going to catalyze and reflect on early- to mid-term COVID-19 impacts.*

- *Primary and secondary-source research technical scope and time management includes:*
  - ✓ *Most important* 500+ phone calls made and e-mails executed.
  - ✓ *Most valuable* 2,000+ electronic sources reviewed.
  - ✓ *Most relevant* 250+ organizational contacts identified as having relevant experience or information for this project.

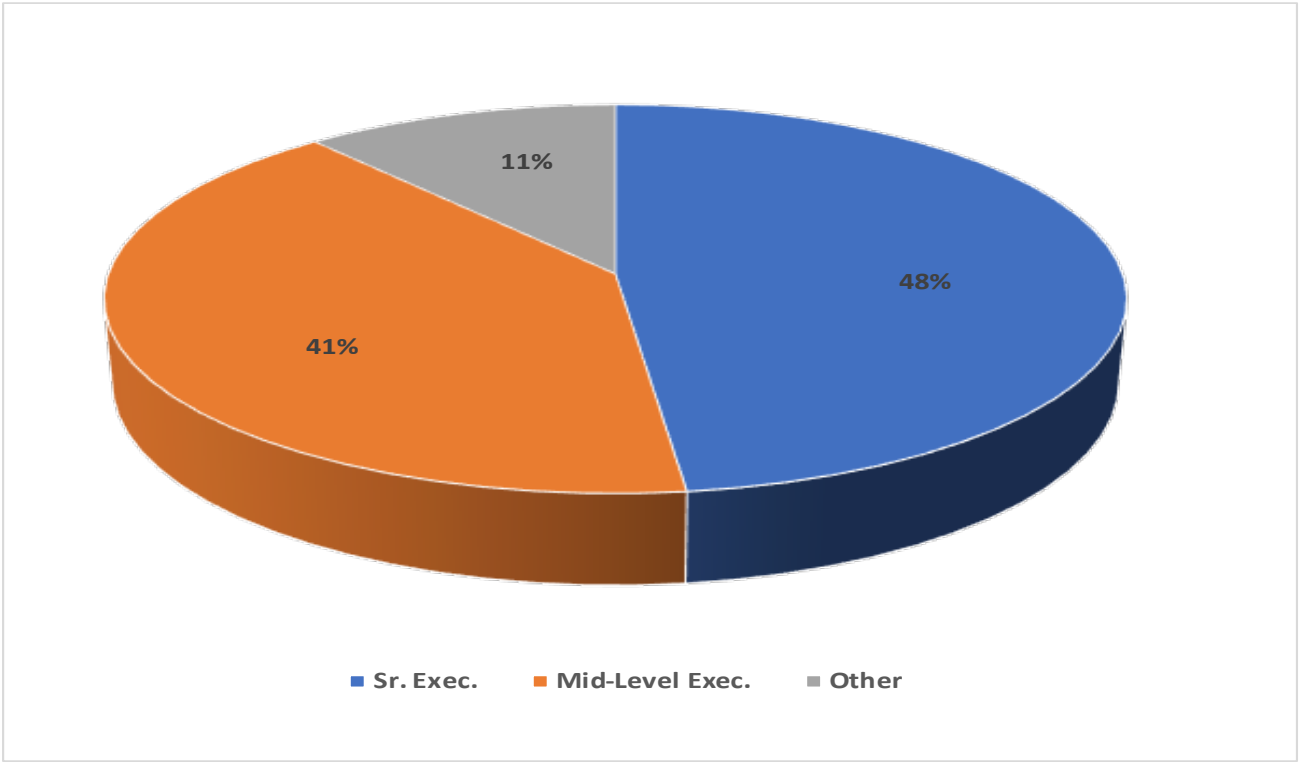
Primary Source Contacts, by Org. Type

[260 total: April 2020 Update]



Primary Source Contacts, By Position

[April 2020 Update]



SYNTHESIS PARTNERS, LLC

This slide does not contain any proprietary, confidential, or otherwise restricted information.

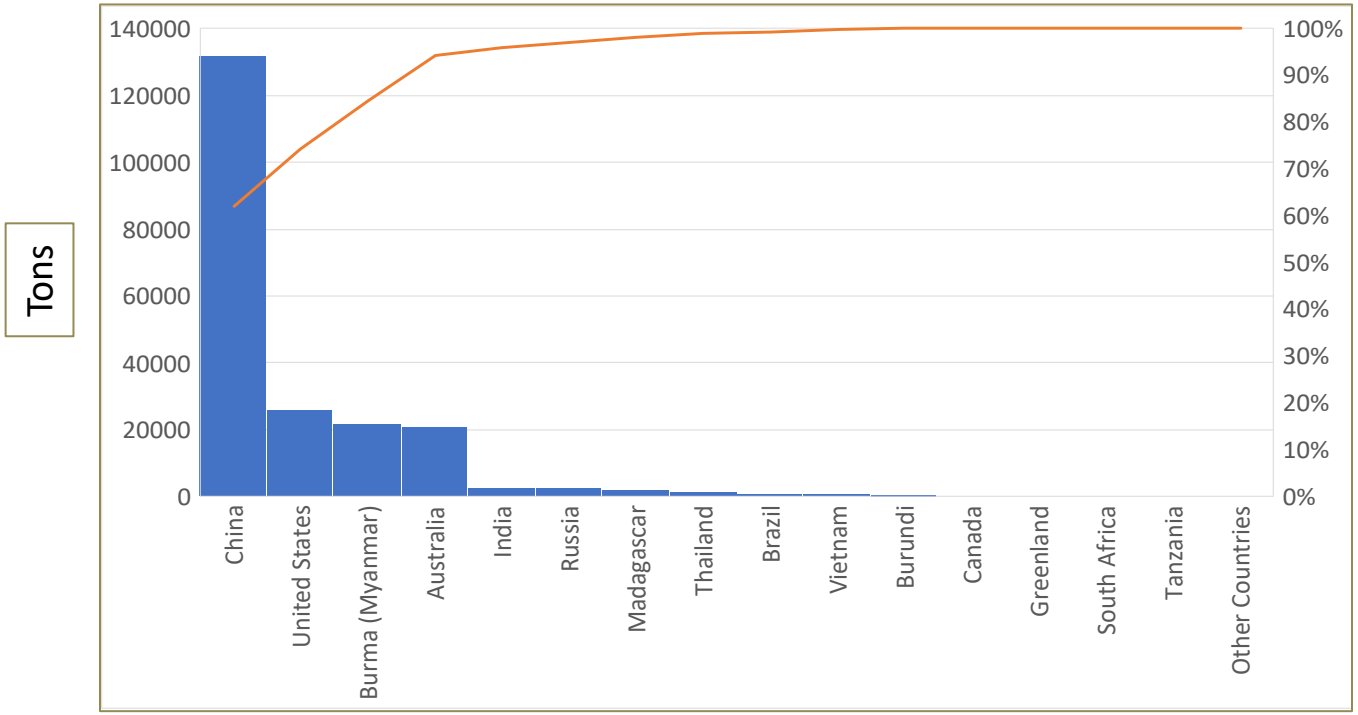
Rare Earth Production: 2019

- U.S. mines
  - US domestic production of Rare Earth mineral concentrates, *all of which were exported [to be processed and refined],* increased to 26,000 tons, a 44% increase compared with that of 2018.
  - US mines produced an estimated $82.2 billion of raw mineral [not just REs] materials in 2018 – a three (3) percent increase over the revised total of $79.7 billion in 2017.

- Global mines
  - Global rare earth oxide equivalent mine production estimated to have increased to 210,000 tons, an 11% increase compared with that of 2018.
  - China continues to dominate the global supply of rare earths. According to China's Ministry of Industry and Information Technology, the mine and separation production quotas for 2019 were 132,000 tons and 127,000 tons, respectively.

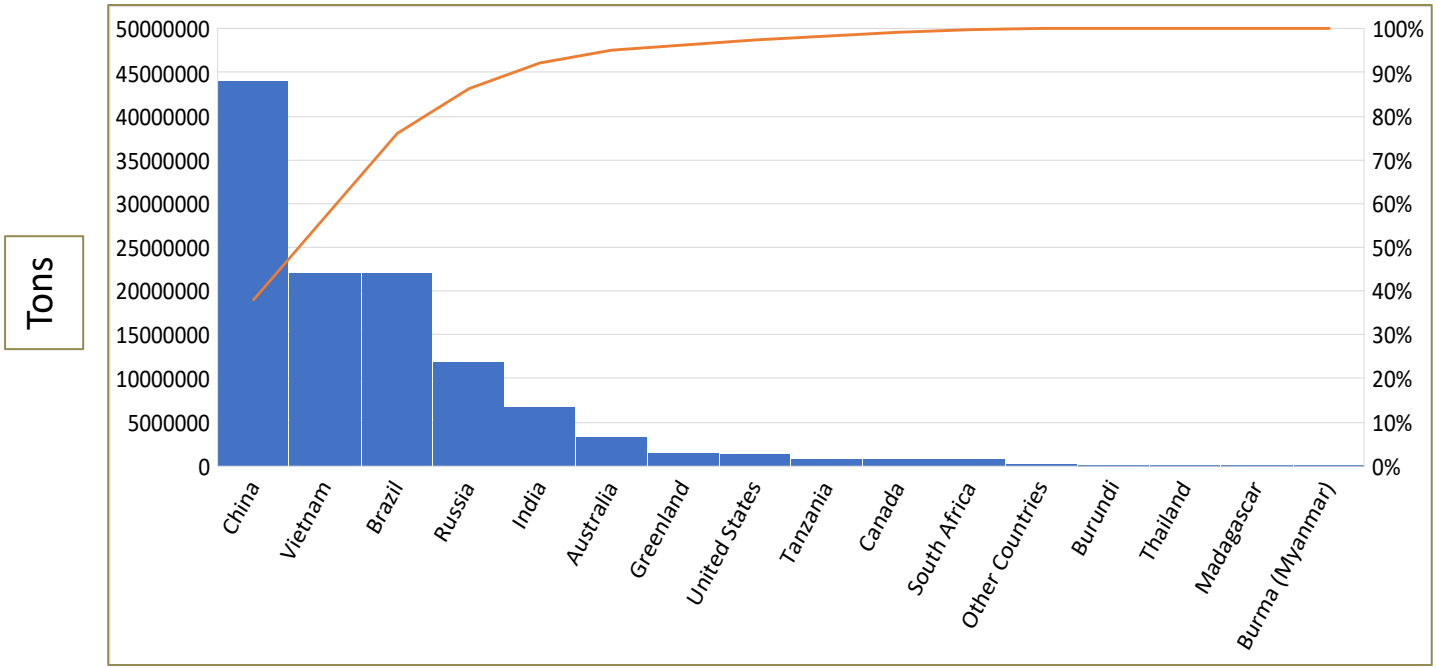
Source: U.S. Geological Survey, Annual Mineral Commodity Summaries, 2018 to present (https://www.usgs.gov).

Global Rare Earths Mine Production: 2019



Source: SP LLC chart based on data from *Rare Earths*, Joseph Gambogi, U.S. Geological Survey, Mineral Commodity Summaries, January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed 02/10/20.

Global Rare Earths Reserves: 2019



Source: SP LLC chart based on data from *Rare Earths*, Joseph Gambogi, U.S. Geological Survey, Mineral Commodity Summaries, January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed 02/10/20.

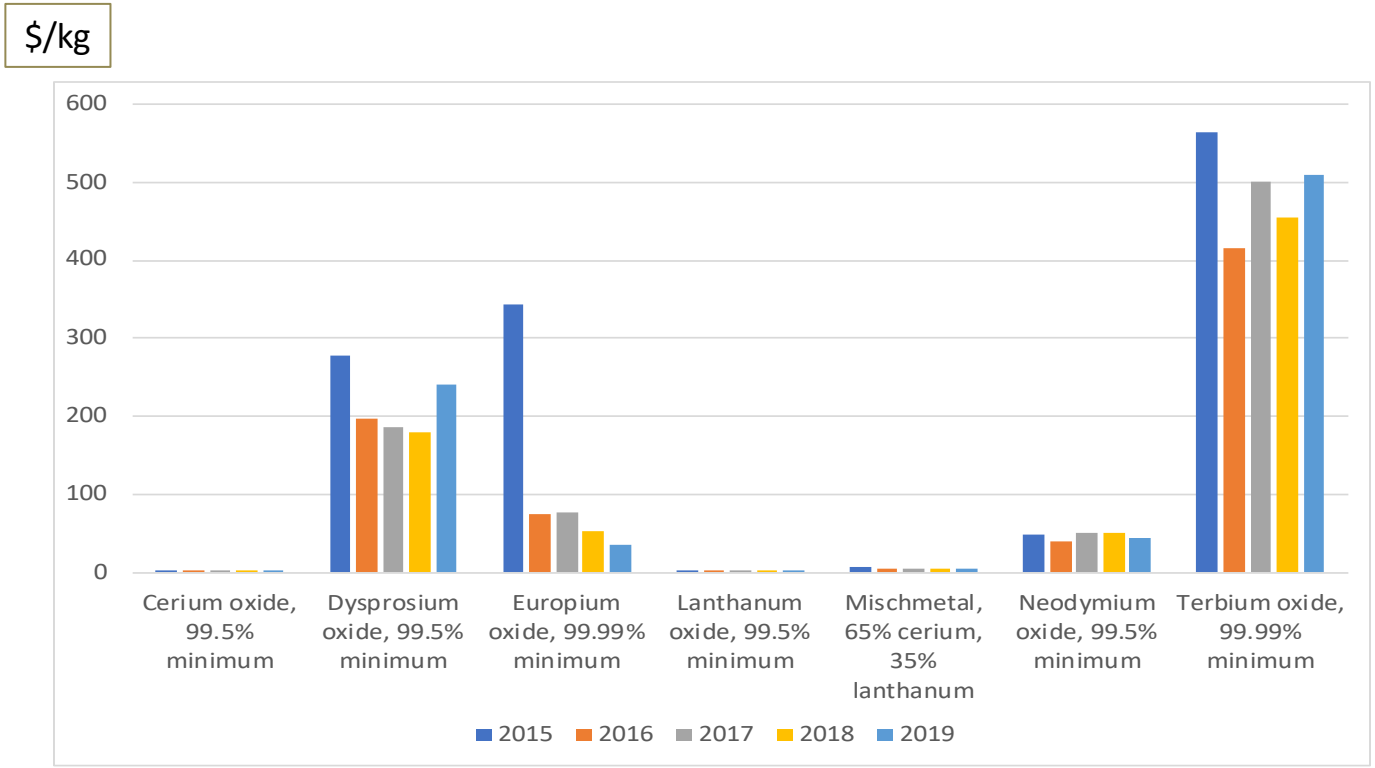
Selected RE Price Trends 2010-2019

Monopoly-market forces that repetitiously restrict, flood, restrict … with sharp affects on prices:

- The 2010 Chinese quotas artificially increased prices, with neodymium reaching peaks of $270/kg, dysprosium $1,600/kg and praseodymium $225/kg.
- Following the 2010 production shortage, Chinese-led market "flooding," caused prices to decline between 2011 and 2015 to $48/kg for neodymium, $278/kg for dysprosium and $75/kg for praseodymium.
- Since then the price of dysprosium and neodymium has declined to $172/kg and $62/kg, respectively.
- Unstable, monopoly price points have made investors wary of engaging in equity investment within the rare earth sector, with the entire prospect considered to be high-risk, low-reward.
- The growth of EVs, alongside continued monopoly market forces, mean prices will be unstable over the medium term, making proactive investment into new projects challenging for the private sector alone – and likely need to be based on long-term national interests.

Source: RE price data from Edison Research 2019 at https://www.edisongroup.com/edison-explains/electric-vehicles-and-rare-earths/; accessed 24 March 2020.

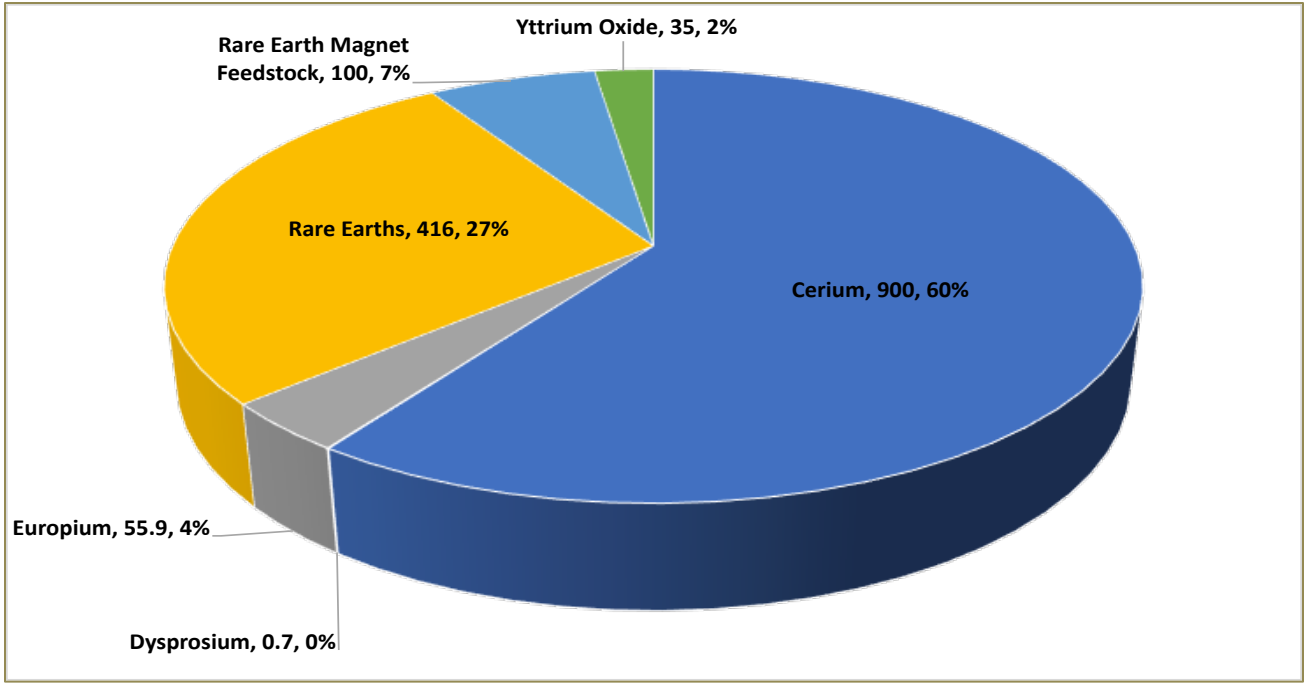
RE Oxide *Average* Annual Prices, 2015-2019



Source: SP LLC chart based on data from *Rare Earths*, Joseph Gambogi, U.S. Geological Survey, Mineral Commodity Summaries, January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed 02/10/20.

US Government Rare Earth Stockpiles:

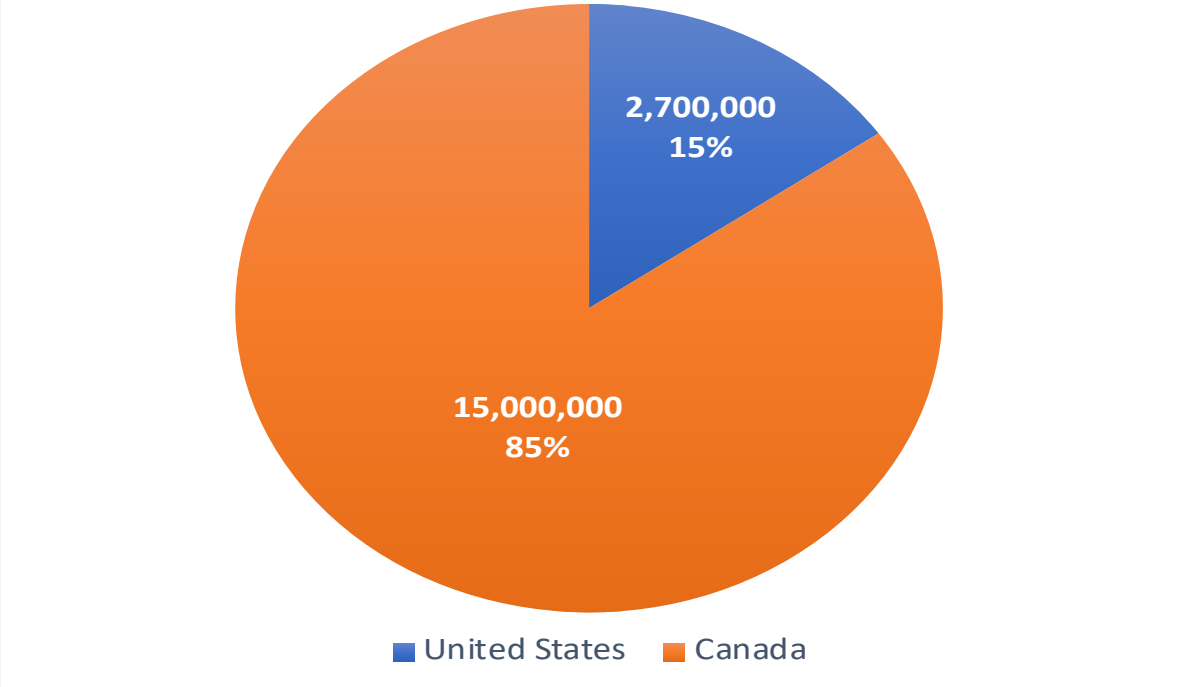
Inventory, Plus Potential Acquisitions as of FY 2020 (Tons)



Source: SP LLC chart based on data from *Rare Earths*, Joseph Gambogi, U.S. Geological Survey, Mineral Commodity Summaries, January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed 02/10/20.

North American Rare Earth Resources

Measured and Indicated Resources of Rare Earths (Tons)



Source: SP LLC chart based on data from *Rare Earths*, Joseph Gambogi, U.S. Geological Survey, Mineral Commodity Summaries, January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed 02/10/20.

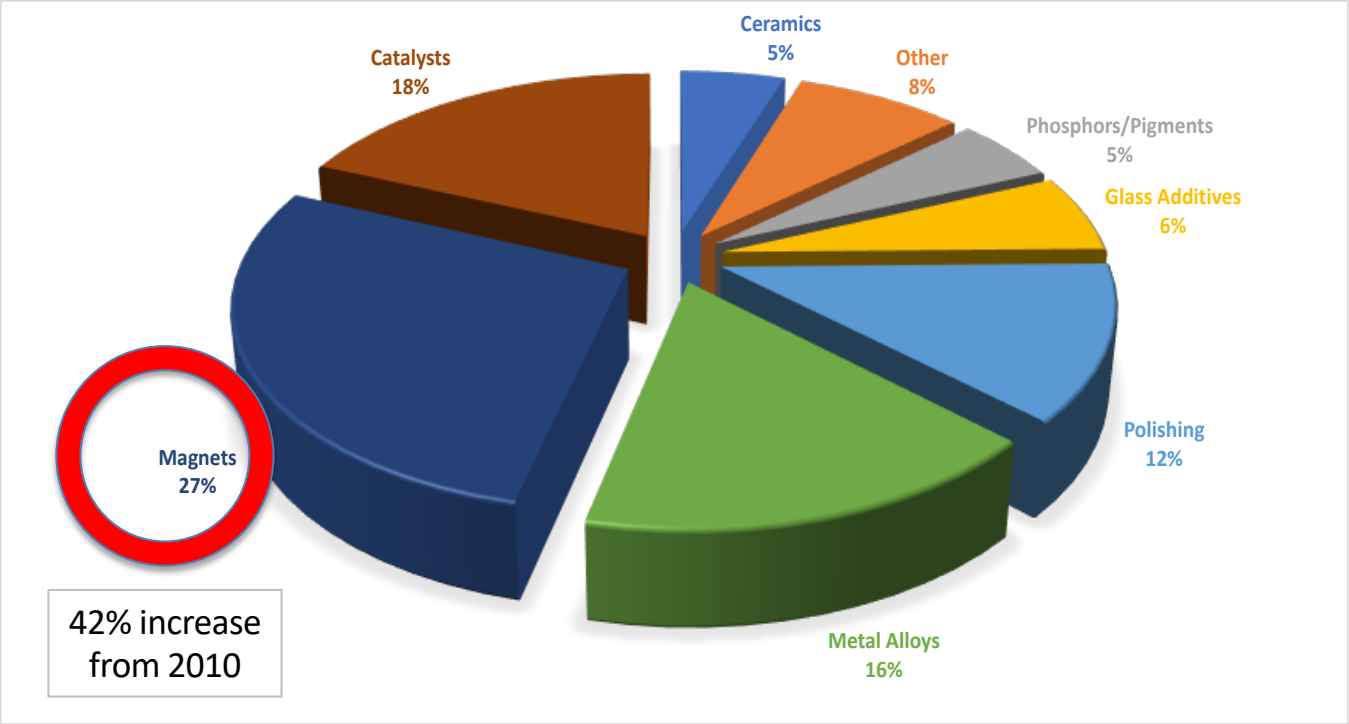
Typical Composition of NdFeB Alloy

Main Elements within NdFeB	Weight Percentage
• Iron (Fe)	64.2% – 68.5%
• Neodymium(Nd)	29% – 32%
• Boron (B)	1.0% – 1.2%
• Dysprosium (Dy)	0.8% – 1.2%
• Aluminum (Al)	0.2% – 0.4%
• Niobium (Nb)	0.5% – 1%

- The most common commercial NdFeB magnets are of the *sintered* type, which displays stronger magnetic force and better performance than other types.

Source: https://www.neodymiummagneti.com/magidea/ndfeb-magnets-production-process/; accessed 5 Dec 2019

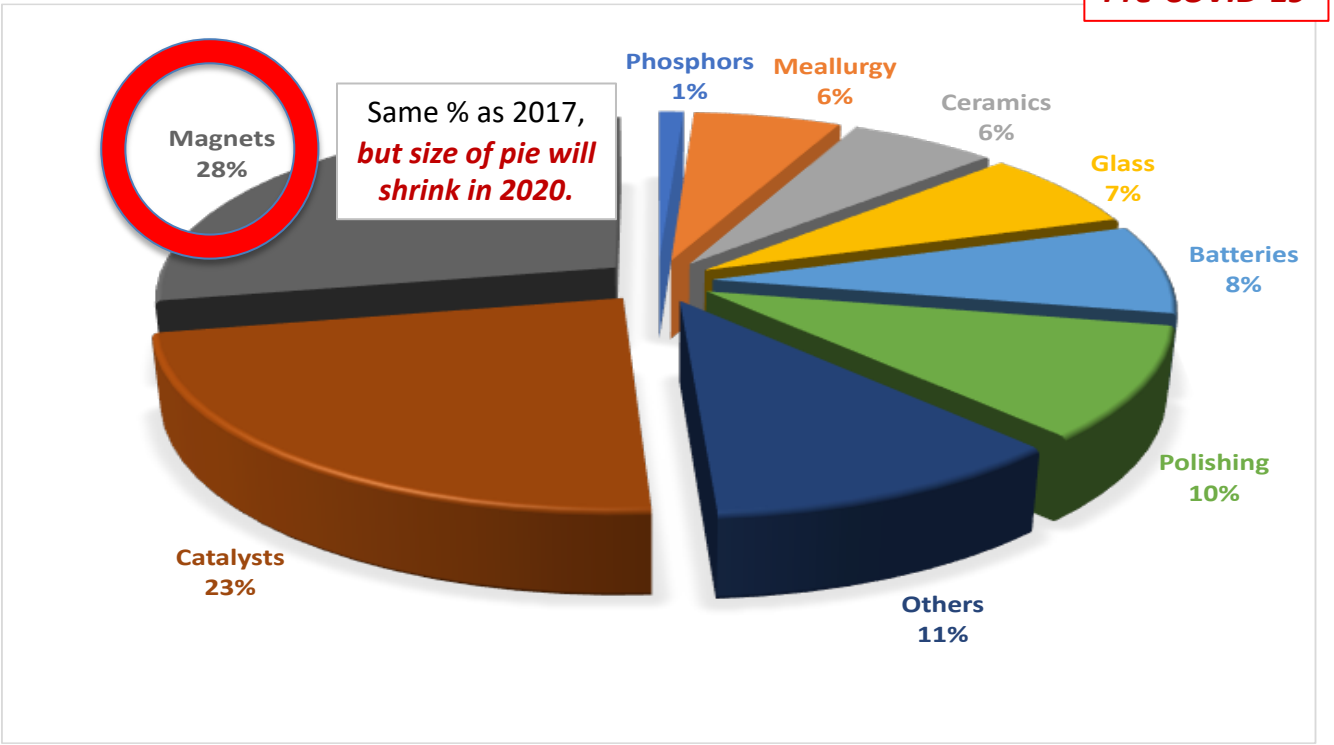
Rare Earth Element Applications: 2017



Source: SP LLC chart based on data from Alkane Resources company presentation linked: https https://seekingalpha.com/article/4124575-look-rare-earths-ev-magnet-metals-miners; accessed 13 Nov 2019.

Rare Earth Element Applications: 2021 Projections

Pre-COVID-19



Source: SP LLC chart based on data from "Rare Earths - Powering the Future", Canada Rare Earth Corp, Nov. 2017, http://www.canadarareearth.com/upload/documents/crec_investor_presentation_nov2017.pdf, accessed 02/25/20.

Key RE Supply Chain Bottlenecks

Base RE Supply: Many Companies, Many Mines, Many Choices.

REE Recovery

- Leaching → Tailings
- Oxalate Precipitation → **RE Oxalates**
- Distillation/Crystallization → Base Metal Precipitation → Mixed Metal Hydroxides

China Dominates: Thorium Radioactivity Mitigation Challenge.

RE Oxalates Purification

- Calcination → Nitric Acid Digestion → Pure C02
- Ce & Th Precipitation → Th Solids to Licensed Disposal; Ce to Stockpile.
- REE Precipitation → Purified 98%+ Pure TREO Powders

China Dominates: Environmental Mitigation Challenge.

Separation of Purified TREO Powders

- 98%+ Pure, Ce-depleted, Near Th-Free TREO Powders.
- Separation and refinement by hydrochloric acids.

Metal Alloys for EV Traction Drive Motor Magnets.

NA Supply Chain Note: Environmentally responsible processes are feasible, e.g.,by using closed loops to recycle reagents and H20. But thorium, leach ponds and tailings remain a legacy clean-up issue. Information on clean-up and remediation and their added costs to life-cycle RE-based electronic product ownership and use is scant.

Emerging Post-Chinese Era in 2020s?

China still dominates separation and refining of RE concentrates to produce oxides, metals and alloys.

But more options than 10 years ago, re: operational mines with capability to separate RE oxides, subject to cost and environmental challenges (alpha order, **NA**)**:**

- Alkane Resources (Australia)
- **Avalon Advanced Materials (Avalon Rare Metals) (Canada)**
- CBMM (Araxá Project, Brazil)
- **Great Western Minerals Group (Canada)**
- JSC Solikamsk Magnesium Works (Russia)
- Lynas Corporation (Australia)
- **MP Materials (Mountain Pass, NV, USA)**
- Peak Resources Ltd. (Australia)
- Pensana Metals Ltd. (Australia)
- **Rare Element Resources Ltd. (Bear Lodge, WY) (Canada)**
- Showa Denko Rare-Earth Vietnam Co., Ltd. (Japan & Vietnam)
- Tantalus Rare Earths (Germany)

And new USA Options Emerging:

- ✓ **Lynas + Blue Line Corp. (TX)** win DoD HRE Processing Pilot (April 22, 2020) (TX, USA).
- ✓ **USA Rare Earth (JV partner with Texas Mineral working Round Top Mt.) acquires US RE permanent magnet mfg. capability from Hitachi Metals America, Ltd.** (April 7, 2020) (TX, USA).
- ✓ **Others [placeholder].**

Source: SP LLC NA RE-to-Magnet Supply Chain Database, 2020.

Selected Companies with New RE Mining, Processing and Separation Technology Options

Alphabetical order, **(Partial or full operations located in NA)**:

- Arafura Resources Limited (Australia)
- **Aurex Energy Corp. (Canada)**
- Cadence Minerals (UK)
- **Canada Rare Earth Corp (Canada)**
- **Commerce Resources Corp. (Canada)**
- **Eagle Plains Resources Ltd. (Canada)**
- **Geomega Resources (Canada)**
- Hastings Technology Metals Limited (Yangibana Project, Brockman Project) (Australia)
- Northern Minerals (Australia)
- Oro Verde Limited - Ionic Rare Earths Limited (Australia)
- **Quest Uranium Corporation a/k/a Quest Rare Minerals (Canada)**
- Rainbow Rare Earths (Guernsey)
- Tanbreez (Greenland)
- TriArk Mining (Russia)
- **Ucore Rare Metals Inc. (Canada)**

Cautionary note: Successful RE-to-magnet alternatives generally require approx. 7-10 years RDT&E and $100s of millions in stable investment.

Source: SP LLC NA RE-to-Magnet Supply Chain Database, 2020.

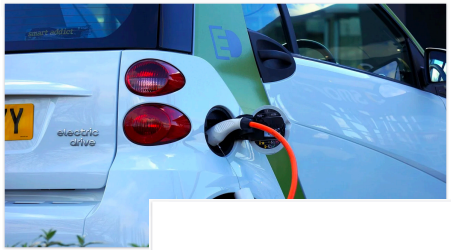
NA RE-to-Magnet Supply Chain Database: *Interim*, Sample View

COMPANY SELF DESCRIPTION	WEBSITE	ORGANIZATIONS	Country	State	Estimated Annual Revenue (in millions) 2019	EST. Employee Count 2019	Category Mining and Milling Company Oxide Manufacturer Metal and Alloy Manufacturer Magnet Manufacturer NdFeB Magnet Manufacturer Magnet Recycler Magnet Manufacturer Motor Manufacturer Motor Component	Confirmed Automotive Supplier Tier 1 Tier 2 Tier 3 OEM Confirmed None = 0 None Found = 0.5	Unknown if Automotive Supplier Tier 1 Tier 2 Tier 3 Mining	Link to the Automotive Industry
Haynes International develops, manufactures, markets and distributes nickel and cobalt-based alloys in sheet, coil and	https://www.haynesint	Haynes International Inc	USA	Indiana	$491.00	1179	Metal and Alloy Manufacturer	0.5	2,3	None Found
Chinese metals and mineral trading company headquartered in Beijing. It is a state-owned corporation under direct	https://www.minmeta	China Minmetals Corporation	China	Beijing	$20,000.00	177,000	Metal and Alloy Manufacturer	0.5	3	Copper and Aluminum
Nippon Steel Corporation, was formed in 2012 with the merger of the original Nippon Steel and Sumitomo Metal. The	https://stainless.nippor	Nippon Steel & Sumitomo Metal Corporation (NSSMC)	Japan	Chiyoda	$52,000.00	93,557	Metal and Alloy Manufacturer	3	3	Bulk manufacturer of auto steel https://asia.nikkei.com/Business/Nippon-Steel-devises-lighter-stronger-auto-steel
Wing Enterprises, Incorporated was founded in 1986. The Company's line of business includes the extruding of aluminum	N/A	Wings Enterprise, Inc	USA	California	$11.20	200	Metal and Alloy Manufacturer		1	N/A
Designs and manufactures frameless traction motors for applications ranging from light metropolitan tramways to heavy	http://www.abb.us	ABB	Switzerland	Zurich	$28,000.00	132300	Metal and Alloy Manufacturer Magnet Manufacturer Motor Manufacturer	1,2, 3		Does research on electric power drives and electric machine drives. ABB Automotive provide a comprehensive range of solutions to automotive
Less Common Metals Ltd is a world leader in the manufacture and supply of complex alloy systems and metals and are specialists	www.lesscommonmet	Less Common Metals	England	Cheshire	N/A	N/A	Metal and Alloy Manufacturer Magnet Manufacturer Specialty Materials and Chemicals	0.5	3	LCM produces Neodymium-Boron-Iron and Samarium-Cobalt alloys for the permanent magnet industry, supplied in powder, strip cast flake or cast ingot forms
Aluminum Corporation of China Limited (Chinalco)Chinese company listed in Hong Kong SAR and in New York	http://www.chalco.co	Aluminum C China					Oxide Manufacturer			

Initial, broad filter. Refinements in categorization and down-selections on-going.

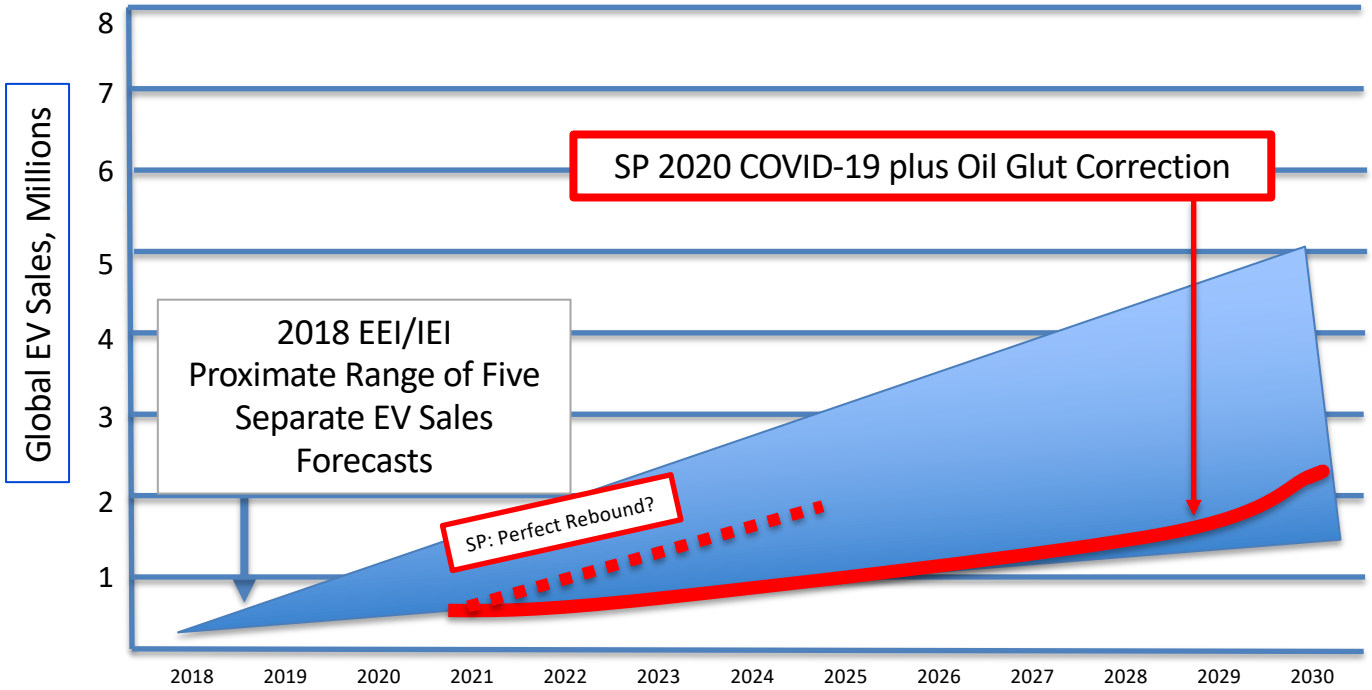
Assessing NdPr Metal Demand

- EVs
  - 0.7-0.8kg of NdFeB magnet per 100 kW of peak motor power.*
  - 1.7kg of NdPr**
- E-Bikes
  - 0.1kg of NdPr*
- Wind Turbines
  - Up to 150kg of NdPr per MW*



Source: * DOE-VTO estimate, 2019; **UBS Bolt Teardown Results Review, 2017; Colin Langan, UBS, US Autos Analyst, Aug. 2017 at https://www.cargroup.org/wp-content/uploads/2017/08/Langan.pdf; and https://seekingalpha.com/article/4124575-look-rare-earths-ev-magnet-metals-miners; accessed 13 Nov 2019.
Photos free commercial use license from https://pixabay.com.

EV Demand Outlooks to 2030



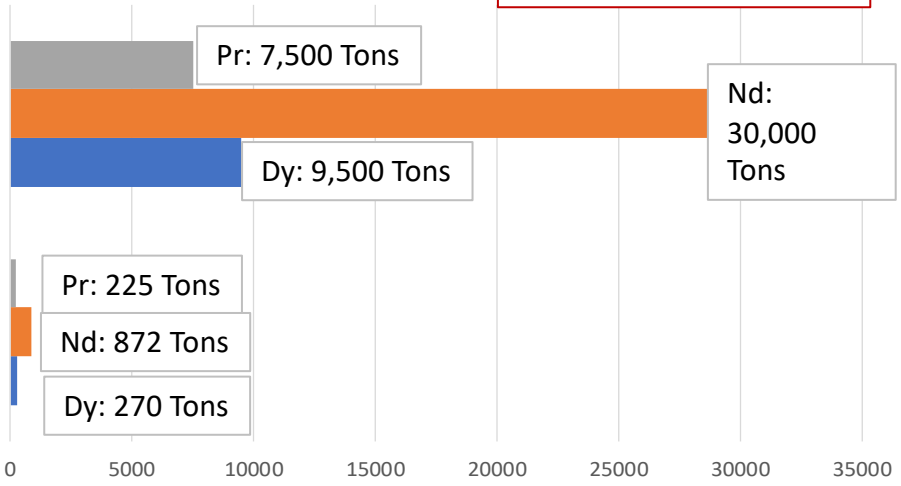
Source: Proximate range of five forecast estimates derived from "Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030," by Adam Cooper (IEI) and Kellen Schefter (EEI), accessed 24 April 2020. SP estimates added.

Estimated Annual Demand for REs for EVs

Missing COVID-19 Impacts

2030 Projection: Based on IEA (2018) and Edison Research (2019) data ranges.

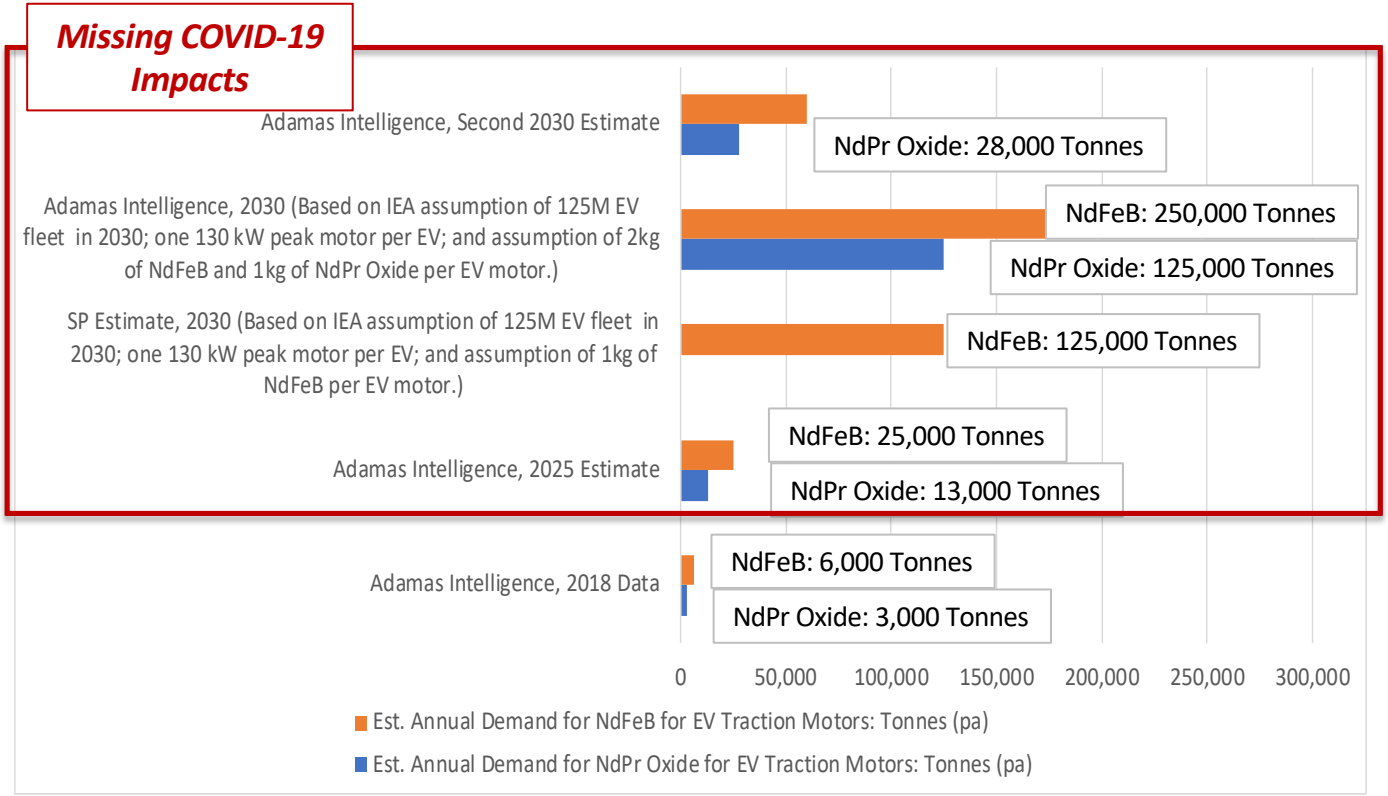
2017 Data: Based on IEA (2018) and Edison Research (2019) data ranges.



	Based on IEA (2018) EV fleet data and Edison Research (2019) data on kgs of neomagnets used for EVs and Hybrid variants. Average of data ranges used.	Based on IEA (2018) EV fleet data projections and Edison Research (2019) data on kgs of neomagnets for EVs and Hybrid variants. Average of data ranges used.
Est. Annual Demand for Pr for EVs: Tons	225	7500
Est. Annual Demand for Nd for EVs: Tons	872	30000
Est. Annual Demand for Dy for EVs: Tons	270	9500

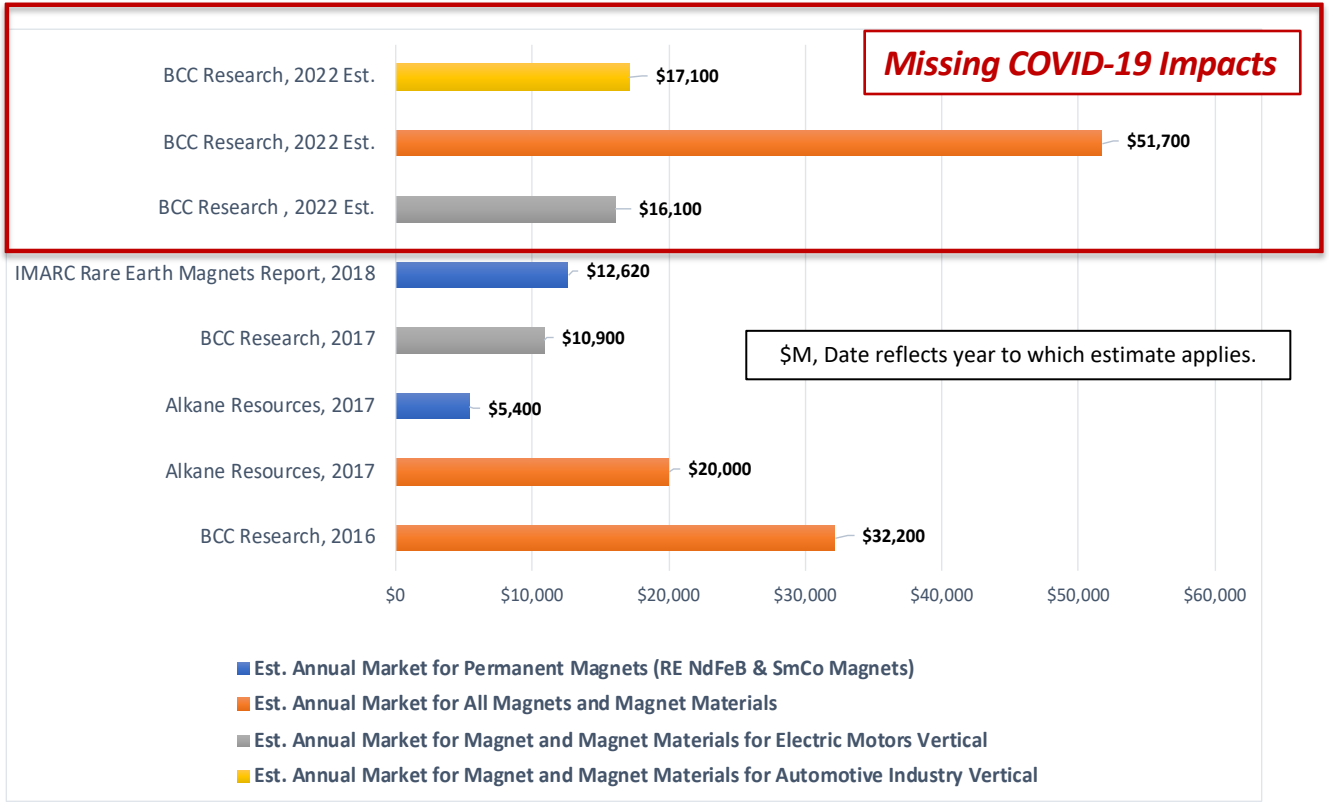
Source: SP LLC chart based on data from IEA 2018 and Edison Research 2019 completed ***pre-COVID-19.***

Estimated Annual Demand for REs for EVs



Source: SP LLC chart based on data from EERE-VTO, IEA and Adamas Intelligence completed ***pre-COVID-19.***

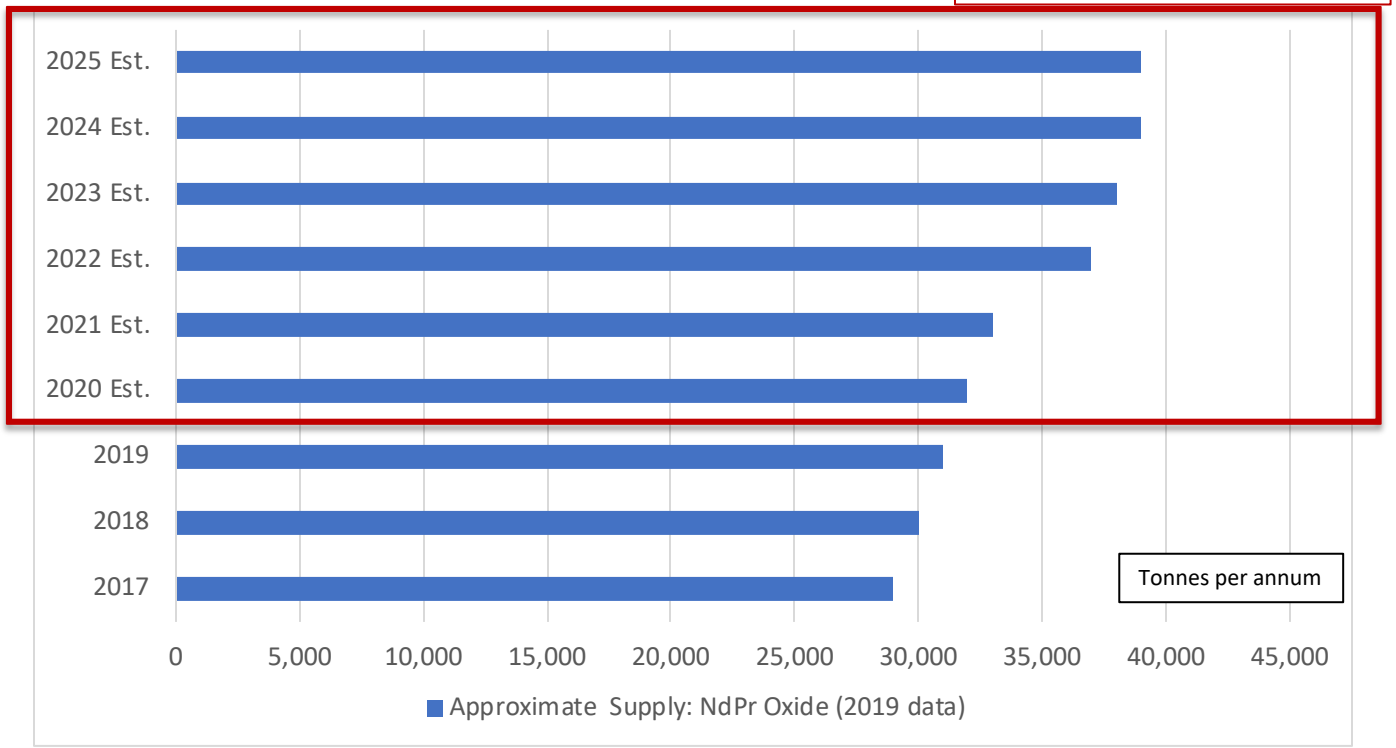
Global Magnet and Magnetics Market Estimates



Source: SP LLC chart and analysis based on data from third-party market research reports completed ***pre-COVID-19.***

Global NdPr Oxide Supply

Missing COVID-19 Impacts

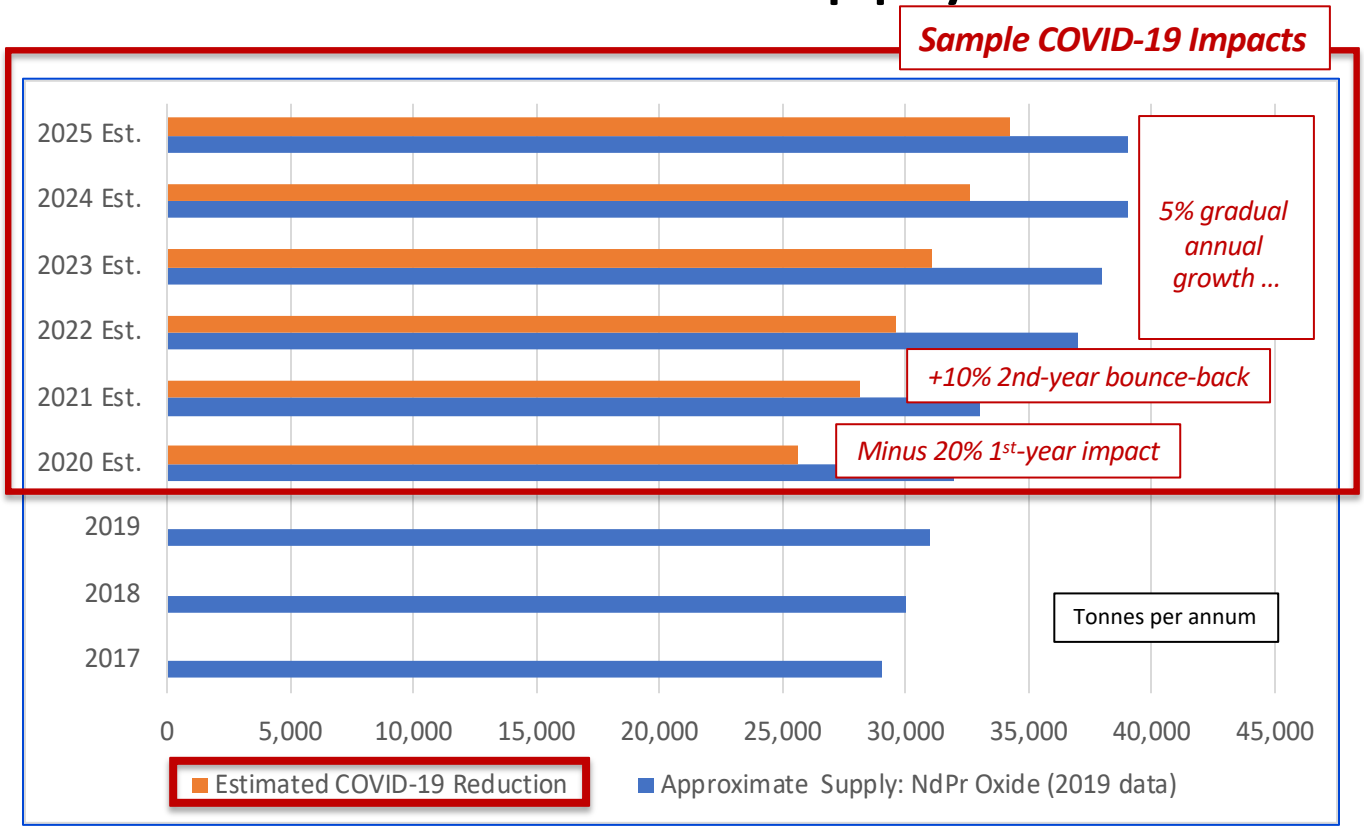


Source: SP LLC chart using 2019 Peak Resources data ***pre-COVID-19.***

SYNTHESIS PARTNERS, LLC

This slide does not contain any proprietary, confidential, or otherwise restricted information.

Global NdPr Oxide Supply Outlook



Source: SP LLC chart and analysis, based on 2019 Peak Resources data ***pre-COVID-19.***

NdPr Oxide Supply Imbalance Outlook

Missing COVID-19 Impacts

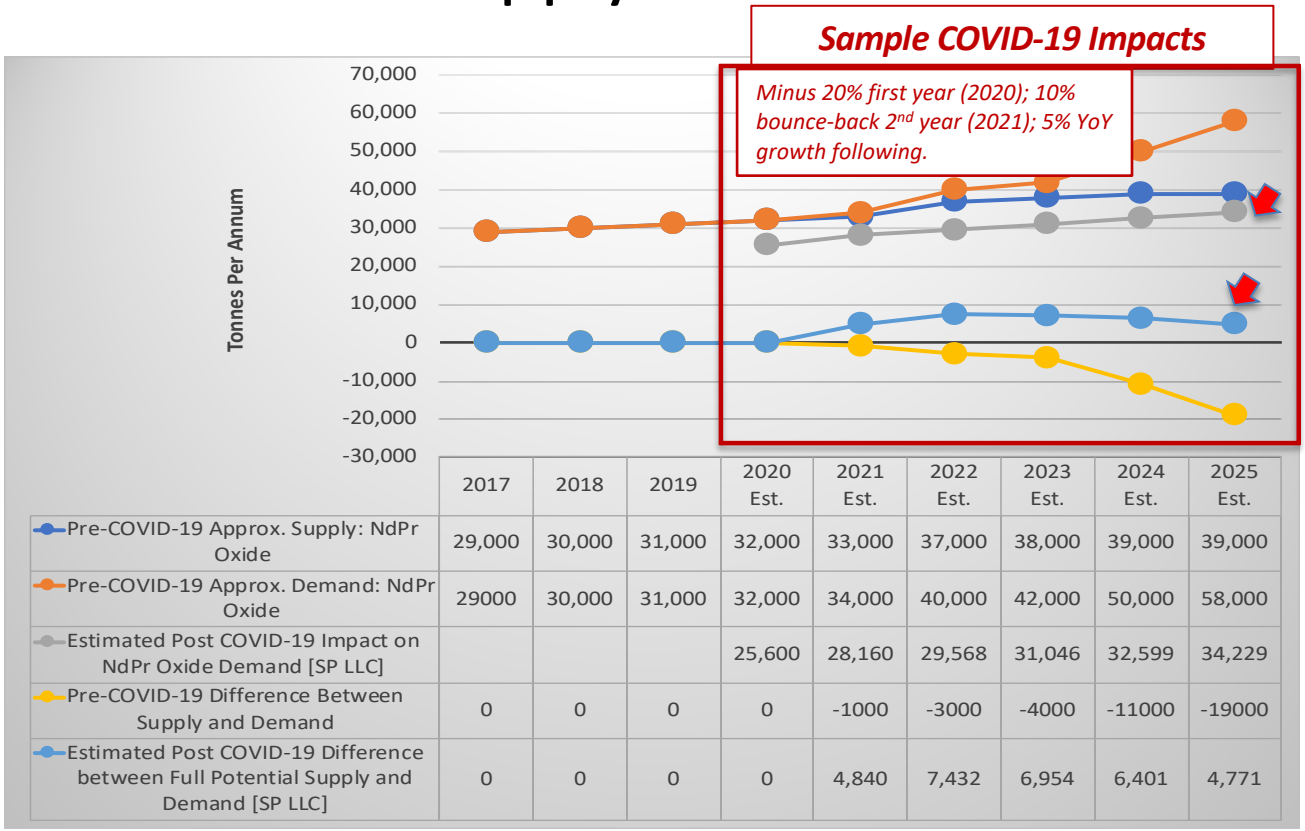
	2017	2018	2019	2020 Est.	2021 Est.	2022 Est.	2023 Est.	2024 Est.	2025 Est.
Approximate Supply: NdPr Oxide	29,000	30,000	31,000	32,000	33,000	37,000	38,000	39,000	39,000
Approximate Demand: NdPr Oxide	29000	30,000	31,000	32,000	34,000	40,000	42,000	50,000	58,000
Difference Between Supply and Demand	0	0	0	0	-1000	-3000	-4000	-11000	-19000

Source: SP LLC chart and analysis using baseline 2019 Peak Resources data ***pre-COVID-19.***

SYNTHESIS PARTNERS, LLC

This slide does not contain any proprietary, confidential, or otherwise restricted information.

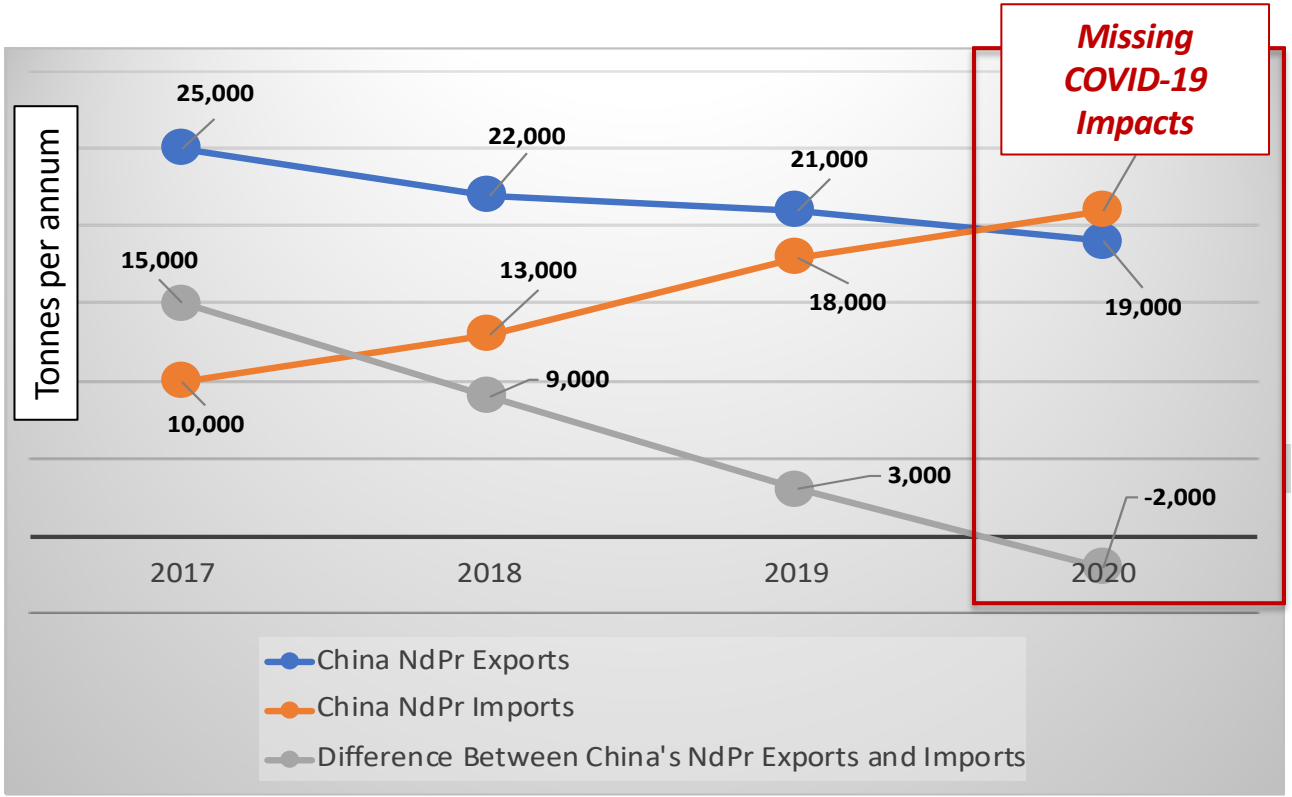
NdPr Oxide Supply Imbalance Outlook



	2017	2018	2019	2020 Est.	2021 Est.	2022 Est.	2023 Est.	2024 Est.	2025 Est.
Pre-COVID-19 Approx. Supply: NdPr Oxide	29,000	30,000	31,000	32,000	33,000	37,000	38,000	39,000	39,000
Pre-COVID-19 Approx. Demand: NdPr Oxide	29000	30,000	31,000	32,000	34,000	40,000	42,000	50,000	58,000
Estimated Post COVID-19 Impact on NdPr Oxide Demand [SP LLC]				25,600	28,160	29,568	31,046	32,599	34,229
Pre-COVID-19 Difference Between Supply and Demand	0	0	0	0	-1000	-3000	-4000	-11000	-19000
Estimated Post COVID-19 Difference between Full Potential Supply and Demand [SP LLC]	0	0	0	0	4,840	7,432	6,954	6,401	4,771

Source: SP LLC chart and analysis using baseline 2019 Peak Resources research completed ***pre-COVID-19.***

Chinese NdPr Oxide Trade Outlook

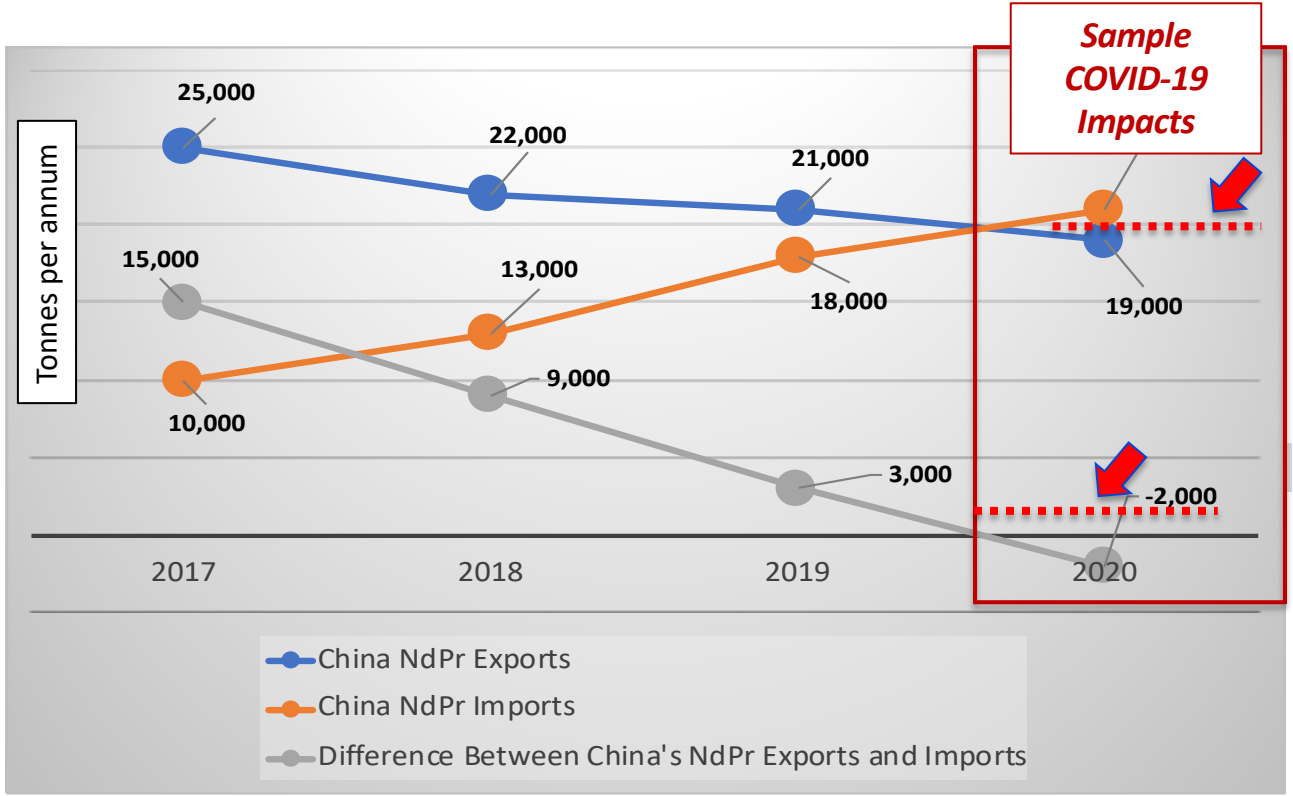


Source: SP LLC chart and analysis using baseline 2019 Peak Resources research completed ***pre-COVID-19.***

SYNTHESIS PARTNERS, LLC

This slide does not contain any proprietary, confidential, or otherwise restricted information.

Chinese NdPr Oxide Trade Outlook



Source: SP LLC chart and analysis using baseline 2019 Peak Resources research completed ***pre-COVID-19.***

SYNTHESIS PARTNERS, LLC

This slide does not contain any proprietary, confidential, or otherwise restricted information.

Thinking Outside the Box

- Seeking technical data to help catalyze NA RE-to-magnet supply chain:
  - Ongoing in-depth conversations with key players in the supply chain.
  - Continuous development of R&D insights and gap-solution thinking.
  - *Next level:* New methods to analyze rapidly changing supply chain data and patterns.

- Seeking disruptive ideas to renew the NA RE-to-magnet supply chain:
  - New mineral-to-magnet processes.
  - New mine-to-REEs recycling and re-use processes.
  - New applications for high-quality REEs that can be uniquely mined, processed and refined in US.

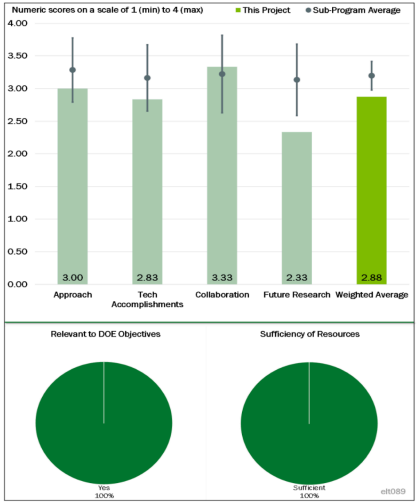
Future Research?: Potential Pathways to NA RE-to-Magnet Supply Chain Renewal

1. Ce-La Catalysts to Reduce $C0_2$
   – Tanbreez, Greenland
2. Holmium for Magnets
   – USA Rare Earth and Texas Mineral Resources (Round Top, TX).
3. RE Abundance in Tailings
   – RE Industry Experts and Energy Fuels Corp. White Mesa Mill (WMM) Mine (Blanding, UT).
4. Robotic *Fast* Separation of RE Metals and Magnets for Re-Use/Recycling
   – Daisy the Robot, Apple (Austin, TX).
5. RapidSX (REE Solvent Extraction) Separation Technology
   – Innovation Metals (Toronto, CA).
6. Magnet Recycling Using New Separation Reactor
   – Geomega Resources (Quebec, CA)

Note: SP does not decide future research topics; above items are for discussion and illustration only.

Response to Reviewer's FY19 Comments

- Technical Accomplishments:
  - Main comment: "The presentation was about what was done rather than providing findings/insights, and need specifics for the work to be effective."
  - Response: Agreed. The staging of this market and supply chain research is such that specific insights and findings are not available by March/April and are only produced after all data has been collected (July/Aug.). Indeed, it is very important that SP does not draw premature conclusions based on partial data collection at AMR.
- Future Research:
  - Main comment: "No further proposed research has been presented."
  - Response: Correct. SP does not decide future research topics. However, the gap analyses and supply chain intelligence that is produced from this work is one key input for VTO decision-makers to decide on future research topics.
- Main Takeaways:
  - While lower scores on Future Research and Tech Accomplishments, as defined by AMR, seem unavoidable FY19 reviewers' overall scoring on Approach and Collaboration demonstrate that this project has a comprehensive approach to data collection, source development, domain modeling, collaborations and gap analyses, and has appropriate funding for the tasks outlined.



Coordination and Collaboration

- Daily collection, coordination and assessment alongside 100s of industry, OEMs, Tier 1-4, universities and other subject matter experts on both public and proprietary basis.

- In-depth engagement with select sources at conferences has been postponed and will resume in August 2020 to support VTO and USDRIVE partnership goals.

- Engagement with DOE federal research labs is on-going, e.g.; SP has accessed and inquired into NREL and ORNL RE supply chain 2020 data-sets and innovative technology development to leverage prior work for this project.

Project Summary

- FY20 research work is at mid-point at time of production of these slides.
  - Interim findings will be vetted and gaps filled via gap-source analysis framework over next period. It is too early to state specific, final findings or insights.
- FY20 research is fundamentally collaborative in that it builds directly on prior and new source relationships and findings.
  - Responsibility of SP is to maintain an increasingly deep pool of researcher, OEM, Tier 1-4 and other relationships with varied, independent viewpoints, to help address VTO decision-needs and objectives.
  - Flexible research, collection and analysis model contributes to understanding "on both sides of the table" → by seeking, accessing and reporting varied, independent viewpoints and best-available data on the NA supply chain to VTO.
  - SP does everything possible to integrate best-practice analytical practices so a diverse range of actionable information and guidance is produced for VTO decision-makers.
- Collaboration and coordination, including with USDRIVE-EETT and VTO stakeholders, is a key ingredient to project success.

Thank you for your interest.

PI:

Christopher Whaling
Co-Founder
Synthesis Partners, LLC
11250 Roger Bacon Drive, Suite 2
Reston, VA 20190
Email: cwhaling@synthesispartners.com